

Serious Errors in the Cost Estimates for the Development and Operation of Directly Shuttle-Derived Heavy Lift Launch Systems

At the August 12th 2009 public meeting,¹ the initial cost estimates for the various options were presented to the public for the first time. The concerns expressed by the Commissioners during deliberations, that no inspirational beyond Earth option was found within the budget guidelines, motivated us to download the presentation and extract the cost estimate values from the sand charts, **Figure 1**. After further analysis we were able to find five serious errors in the cost estimates and made these errors known to the commission two days after the public meeting. Fortunately two of these serious errors have now been corrected based on follow-up discussions we had last week. The purpose of this letter is to address the other three serious errors that, based on our understanding of those same discussions, seem likely to be incorporated into the final report. These three errors are of sufficient magnitude that significant errors could be made in both near and long term policy decisions if they are not corrected. We hope that this letter will be useful in at least bringing into the public record the historical facts and logical inconsistencies that we believe need to be addressed and ultimately reconciled in the final report.

The first serious error relates to the development cost prediction for a Directly Shuttle-Derived Heavy Lift Launch System (SDHLV). The \$28.4 Billion dollar development cost estimate for a SDHLV is simply unsupportable in our view based the historic development cost for the Space Shuttle. The Government Accountability Office (GAO) performed a development cost assessment² of the Space Shuttle in 1975, **Figure 2, 3 & 4**. From these historic development cost numbers it is clear that there is a significant reduction in the statement of work in going from the Space Shuttle to a Directly SDHLV solution. In addition, a Directly SDHLV option naturally shares the benefits of utilizing proven infrastructure, tooling, workforce experience and flight qualified/man-rated systems already in place. Furthermore, we think it is incorrect to apply the same cost estimating safety margin to what is in fact a modification of an existing system vs. any alternate Heavy Lift Launch Systems that are largely 100% new whether it is Ares or EELV.

This significant initial overestimate in the development cost of a Directly SDHLV is further amplified by a positive feedback loop within the overall funding plan. The poorly sequenced technology development plan severely reduces the development dollars available for a Directly SDHLV thereby significantly delaying the Initial Operating Capability (IOC). What remains of this slow trickle of available development dollars is then further consumed by the sustaining cost to keep in place key components of the existing Space Shuttle infrastructure and workforce needed by the Directly SDHLV. This positive feedback loop is amplified still further by the mischaracterization of the DIRECT proposal itself required in part to fit the limitations of the sidemount SDHLV option. The DIRECT plan clearly separates the Jupiter development program into two distinct phases of Core and Earth Departure Stage (EDS), **Figure 5**. In fact the EDS specification is not driven by the Jupiter-130 but by the requirements of the beyond Earth mission and spacecraft architecture trade space. Therefore the supposition that no interim capability is possible until the Jupiter-241 (Jupiter-130 + EDS) is completed is a clear mischaracterization of the DIRECT plan. This significant increase in the statement of work delays the IOC many years significantly increasing the already substantial burden of infrastructure sustaining costs still further.

After correcting for these serious errors, omissions, over simplifications and mischaracterizations of the DIRECT plan the Jupiter-130 will cost less than \$8 Billion dollars to achieve IOC. This estimate is backed up by the Congressional Budget Office's (CBO) own estimate of \$8 Billion dollars (2006 Dollars)³, for a Directly SDHLV system similar to the Jupiter-241 which includes the EDS development cost. The policy implications of a \$20 Billion dollar shift in the Directly SDHLV development cost estimate are significant. Under this lower cost scenario the Jupiter-130 will not only fit the existing budget guidance, close the flight gap and utilize a significantly higher portion of the experienced workforce but would also have an IOC date of 2014 with a

corresponding performance capability that aligns with and accelerates the Orion's beyond Earth orbit focused development effort as well. Based on this corrected cost estimate information, the early dire conclusions apparent in the Commission public deliberations on August 12th 2009 would be significantly reversed. The policy confusion that could result between executive and legislative branches if historic GAO development cost numbers and past CBO cost assessments are somehow overlooked in the final report cannot be understated.

The second serious error relates to the projected operational cost of Directly SDHLV. In order to arrive at an equivalent to the total operational cost of the existing Space Shuttle one must add the cost estimates for the SDHLV, Ground Operations and Orion together. From this, the total operational cost estimate for a SDHLV is projected to be more the 50% higher than that of the existing Space Shuttle and significantly higher than the CBO assessments³. This high cost estimate is completely unsupportable based on over thirty years of the operational cost history of the Space Shuttle⁴, **Figure 6**. As was the case with the SDHLV development cost estimate, the SDHLV operational cost estimate will share much in common with the Space Shuttle. In addition and for the same reason, a significant reduction in the statement of work will also occur with the removal of the Space Shuttle Orbiter from the Heavy-Lift launch stack. Just like the development cost, the operational cost associated with the Heavy-Lift launch stack and system integration is very well known and should not have the same cost estimating margin applied to it as 100% new systems. Taken together we believe that the total operational cost of a Jupiter-130/Orion system should not cost more than the existing the Space Shuttle which operates at about \$3 Billion per year. At the same time, the Jupiter-130/Orion system will deliver a four fold reduction in the cost per kilogram to orbit, a ten fold improvement in crew safety and more than a four fold improvement in mission payload capability (diameter, volume, mass) as compared to the Space Shuttle. From this solid near term foundational improvement over the Space Shuttle, future growth options can then be contemplated once we are through the challenging transition period ahead of us.

The third serious error is the double standard used when estimating the cost effectiveness of commercial COTS vs. Directly SDHLV options. On one hand the commercial COTS providers are generally free of the additional cost burden associated with significant NASA oversight. On the other hand this significant additional cost burden is still assumed for both the Directly SDHLV and Orion spacecraft development efforts. First the existing SDHLV infrastructure, tooling, highly experienced workforce, and systems are just as commercializable by a shift in policy as any new commercial startup alternative. The fact that most commercial COTS approaches require new infrastructure, workforce, and systems development should not be uniquely associated with limited NASA oversight. If anything, a lack of organizational experience should be a cause for more NASA oversight not less. Ironically as it stands now the most experienced commercial organizations are burdened by the most NASA oversight where as the least experienced commercial organizations have the least NASA oversight. While the policy objectives of the COTS program are sound, the bias of only retaining a significant NASA oversight cost burdened on experienced commercial organizations utilizing existing infrastructure and flight proven man-rated systems is neither logical nor consistent. Therefore any policy decisions based on an illogical bias that significantly alters the cost effectiveness between existing and new commercial organizations is equally erroneous.

We sincerely hope the issues we have raised will be utilized in the final report to help in correctly framing the debate concerning the reasonable development and operational cost for a Directly Shuttle-Derived Heavy Lift Vehicle. In addition we hope that the bias shown between experienced and new commercial companies are removed when comparing the cost effectiveness of various options and approaches. We believe that by addressing these issues with the clarity and consistency needed to make sound policy and budget decisions, the ability of the Commission's final report to improve the rate at which political consensus is reached will be significantly improved.

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Appendix

Deep Space - Shuttle Derived - Less Constrained

\$ Billions Then Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	IOC Sub	TOTAL
Commercial Crew																						
STS	3.0	3.2	1.5	0.3	0.6	1.0	0.8	0.3	0.6	0.6	0.6	0.6	0.6								7.7	6.0
ISS	2.1	2.2	2.9	3.0	3.0	3.1	3.2	2.8	2.8	2.8	2.5	2.0	0.3	0.2	0.1						32.4	8.0
Technology Development				0.1	0.3	0.5	0.7	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.1	1.0	1.1	1.1	1.1	1.1		33.0
Other Non-Cx Elements	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.7	0.8	0.7	0.8	0.9	1.0		15.9
In Space Refueling				0.2	0.5	0.7	0.6	0.6	0.5	0.4	0.3	0.4	0.4	0.4	0.5	0.6	0.6	0.6	0.6	0.5		14.6
Beyond LEO Capability																						8.3
Other Cx Elements	0.3	0.3	0.6	0.7	0.7	0.7	0.6	0.8	1.0	0.9	1.4	1.4	1.6	1.8	1.8	1.7	1.9	1.9	2.0	2.1		15.5
Ground Ops	0.3	0.2	0.3	0.4	0.5	0.5	0.5	0.7	1.0	0.7	0.8	1.2	1.5	1.0	1.0	1.6	1.8	1.9	2.0	1.9		24.2
GFE/COTS Lander																						19.8
Sidemount	0.0	0.5	0.5	0.9	1.8	2.2	2.2	2.0	1.8	3.0	3.0	3.0	3.7	3.8	4.0	4.4	4.9	5.1	5.2	5.4	28.4	57.4
Ares-I	1.4	0.7																				2.1
Orion	1.3	1.5	1.5	1.6	1.7	1.9	2.0	2.0	1.6	1.2	0.9	0.9	1.1	1.1	1.1	1.2	1.3	1.3	1.4	1.4	20.3	28.0
TOTALS:	8.9	9.2	8.5	8.7	10.6	11.7	11.8	12.1	12.2	12.4	12.7	12.7	13.0	13.1	13.0	13.4	14.3	14.7	15.0	15.5		

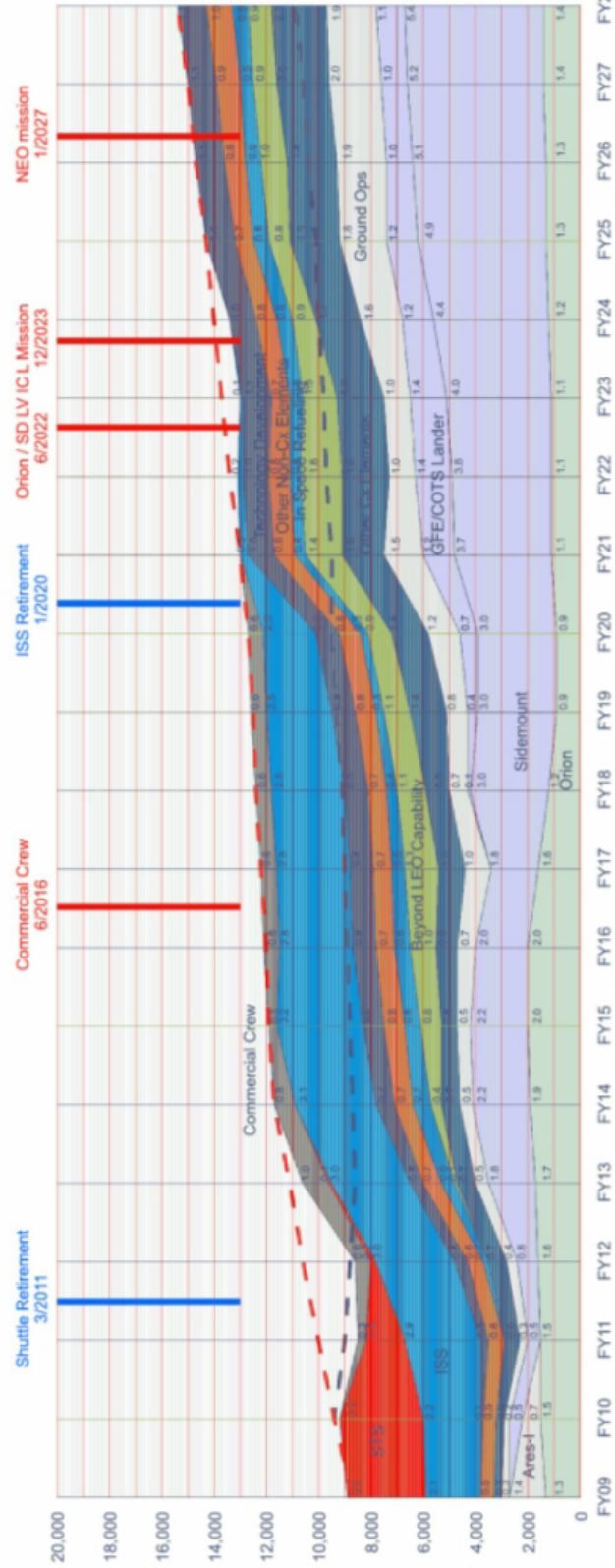


Figure 1: Shuttle Derived Less Constrained – 8/12/09 Cost Assessment with Extracted Numbers

TABLE 1

DOIDE ESTIMATES AND RECORDED OBLIGATIONS
(Dollars in Millions)

Category	Estimate ¹ as of March 1972	Estimate ² as of Nov. 1972	Estimate as of Sept. 1974	Nov 1972- Sept 1974 Increase (Decrease)	Recorded Obligations as of Sept. 30, 1974	Percent of Current Estimate Obligated
Vehicle and Engine Definition and Technology		\$ 121.7	\$ 122.0	\$ 0.3	\$ 121.6	99.7
Main Engine	\$ 412.0	641.3	760.4	128.1	214.8	27.9
Solid Rocket Booster	331.9	494.7	321.3	(173.4)	9.4	2.9
External Tank	301.2	594.5	249.5	(345.0)	35.4	14.2
Orbiter	2,884.9	3,468.2	3,689.1	220.9	707.6	19.2
Launch and Landing	69.0	464.5	507.2	42.7	5.3	1.0
System Management (Includes Reserves)	1,151.0	950.0	1,267.2	317.2	1.8	0.2
Contract Administration		44.9	83.6	38.7	14.0	16.7
Real Year Dollars		\$6,779.8	\$7,009.3	\$229.5		
Total 1971 Dollars	\$5,150.00	\$5,150.0	\$5,200.0	\$ 50.0		
Obligations incurred					\$1,109.9	15.8

¹ The March 1972 estimate was based on 1971 dollars and did not include inflation. The vehicle and engine definition and technology category and contract administration is included in the six major elements.

² This is NASA's first estimate in real year dollars. No cost estimate was made in real year dollars in March 1972 (the date of NASA's commitment to Congress). Between March and November 1972 the program was extended nine months and adjustments were made to realign work tasks among the projects. We estimate that NASA's real year dollar estimate in March 1972 would have been about \$6.556 billion. Thus, the total cost increase between March 1972 and September 1974 would be about \$450 million.

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TABLE 1

ESTIMATED SPACE TRANSPORTATION SYSTEM COSTS
THROUGH 1990 (1971 Dollars in Billions)

<u>Elements</u>	<u>Cost Estimate</u>
Non-recurring Costs	
Space Shuttle Developmental Costs--Design, Development, Test and Evaluation (DDT&E)	\$5.150 ^a
Orbiter Inventory (Refurbishment of the two development orbiters and production of three orbiters)	1.000 ^a
Facilities (including two launch sites)	
NASA \$.300 ^a	
DOD <u>.500</u>	.800
Modifications and Requirements for expendable stage (Interim Upper Stage)	.290
Reusable Space Tugs	
DDT&E \$.638	
Investment <u>.171</u>	<u>.809</u>
	\$8.049
Recurring Costs During Operations	<u>8.050^b</u>
TOTAL	<u><u>\$16.099</u></u>

^aBaseline estimate.

^bA baseline estimate has been established for the average cost per flight of the space shuttle based on a 439 flight mission model rather than the 581 flight mission model used in this analysis.

Figure 3: Space Shuttle Total Cost Breakout , GAO Report #093513, February 1975, page 19

\$ Millions	1971	2010	2010	
Orbiter	\$ 2,711	\$ 15,965	5%	\$ 798 Avionics
3 Orbiters	\$ 1,000	\$ 5,890	10%	\$ 589 2 Test Flight Vehicles
Systems Management	\$ 931	\$ 5,484	30%	\$ 1,645
Contract Administration	\$ 61	\$ 362	17%	\$ 62
Launch and Landing	\$ 373	\$ 2,195	20%	\$ 439
Configurations	\$ 90	\$ 528	17%	\$ 90
Main Engine	\$ 565	\$ 3,330	5%	\$ 166
Solid Rocket Booster	\$ 236	\$ 1,390	5%	\$ 70
External Tank	\$ 183	\$ 1,080	150%	\$ 1,620
NASA Facilities	\$ 300	\$ 1,767	50%	\$ 884
	\$ 6,450	\$ 37,991		\$ 6,362
			STS-Jupiter	17%
			Margin	25%
			Jupiter-130	\$ 7,952

Figure 4: Directly Shuttle Derived Heavy Lift Vehicle Development Cost Estimate

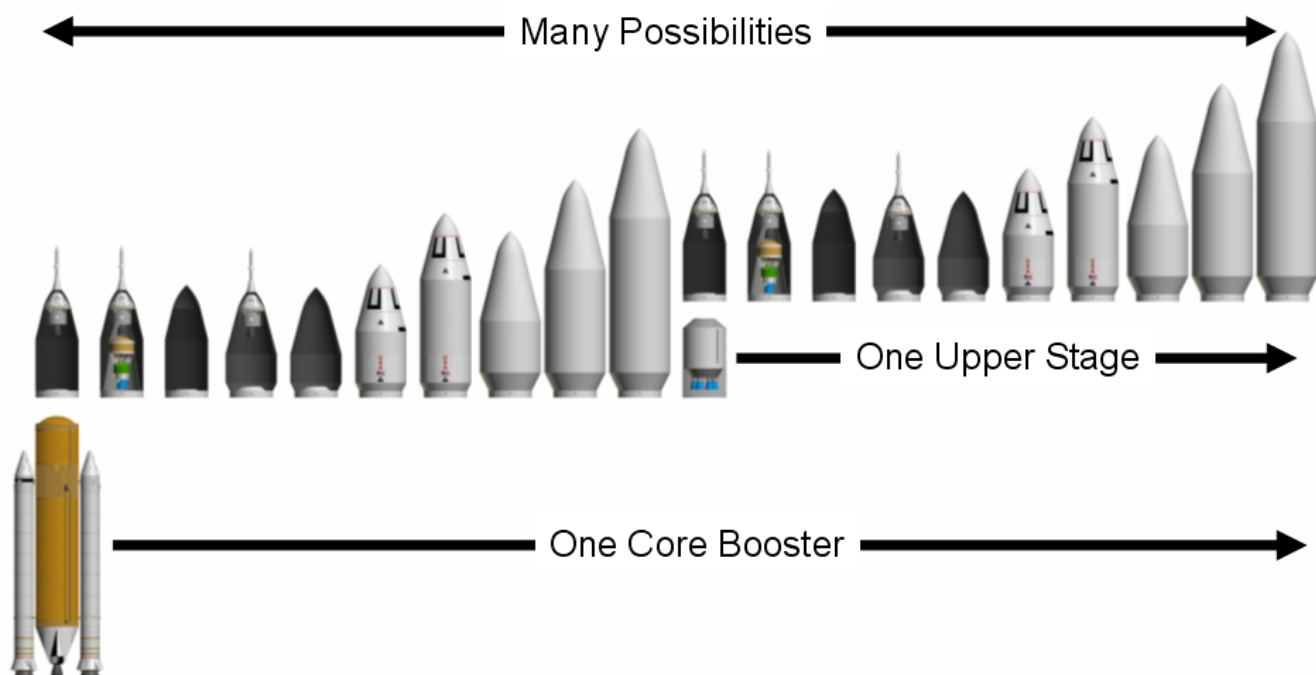


Figure 5: High Level Overview of the Jupiter Launch System Family

Mission Directorate:	Space Operations
Theme:	Space Shuttle
Program:	Space Shuttle Program

Plans for FY 2009

There are a number of significant activities planned for SSP in FY 2009. The Space Shuttle is manifested to fly a total of five missions to the ISS. At the same time, NASA and the Space Shuttle have a number of major transition milestones set for FY 2009, including the first flight test of Ares I hardware (Ares I-X) and the potential retirement of Space Shuttle Atlantis.

Project Descriptions and Explanation of Changes

The pages that follow provide a detailed description of the tightly-coupled project activities of the Space Shuttle program that support the mission manifest for FY 2009. The table below provides a detailed look at the planned budget for each of these projects for FY 2007 to FY 2011.

RY (\$ millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
TOTAL SPACE SHUTTLE	3,315.3	3,266.7	2,981.7	2,983.7	95.7
<u>FLIGHT AND GROUND OPERATIONS</u>	<u>1,066.7</u>	<u>1,121.8</u>	<u>1,031.2</u>	<u>955.9</u>	<u>0.0</u>
Launch and Landing (KSC)	746.3	780.4	705.5	632.5	
Landing Operations (DFRC)	3.0	3.1	4.0	4.0	
Mission Operations	214.5	236.5	221.4	220.8	
Flight Crew Operations	87.6	87.6	86.3	83.0	
Space and Life Sciences	11.2	12.6	12.1	13.1	
Flight/Ground Operations Transition & Retirement	4.2	1.6	2.0	2.4	
<u>FLIGHT HARDWARE</u>	<u>1,717.2</u>	<u>1,674.6</u>	<u>1,460.9</u>	<u>1,413.0</u>	<u>0.0</u>
Orbiter	620.3	504.8	459.1	638.4	
EVA	0.2	0.2	0.2	0.2	
External Tank	298.7	313.2	253.6	169.2	
Reusable Solid Rocket Motors	326.0	369.0	301.6	114.9	
Space Shuttle Main Engine	264.5	240.0	193.8	178.0	
Solid Rocket Boosters	165.2	154.1	136.8	98.2	
SSC Test Support	25.6	33.2	30.0	24.7	
Flight Hardware Transition & Retirement	16.7	60.1	85.8	189.4	
<u>PROGRAM INTEGRATION</u>	<u>511.4</u>	<u>470.3</u>	<u>489.6</u>	<u>614.8</u>	<u>95.7</u>
Systems Engineering and Integration	90.1	86.7	74.0	77.4	
Safety and Mission Assurance	25.1	30.6	54.8	42.2	
Flight Software	111.1	112.4	100.9	107.4	
Flight Operations and Integration	58.0	52.2	54.8	55.0	
Management Integration and Planning	34.9	31.1	26.7	26.7	
Business Management	66.8	66.5	62.1	64.1	
Propulsion Systems Engineering & Integration	18.5	19.5	16.6	18.0	
Space Shuttle Propulsion Systems Integration	15.5	20.6	19.3	20.7	
Construction of Facilities	20.1				
Safety and Sustainability	3.4	1.7			
Mission Directorate Support	29.7	8.6	12.2	12.2	
Contract Administration	26.5	26.0	25.5	23.4	
Closed Accounts	8.9	1.0	1.0	1.0	
Program Integration Transition & Retirement	2.7	1.4	1.5	1.7	
Severance and Retention		12.0	40.3	165.0	95.7
<u>HURRICANE RECOVERY</u>	<u>20.0</u>				
Hurricane Recovery	20.0				

Note: FY 2009 President's Budget Request is in Direct Dollars and represents the July 2007 Operating Plan for the 2007 actual, the 2008 Omnibus Appropriations Act (P.L. 110-161) for the 2008 enacted, and the 5-year Proposed Budget Estimates for 2009 through 2013.

Spa-12

Figure 6: Space Shuttle Operational Cost Breakout⁴

References

- 1 Human Space Flight Committee, Public Meeting, August 12, 2009, Presentation by Dr Sally Ride
link: (http://www.nasa.gov/ppt/378555main_02%20-%20Sally%20Charts%20v11.ppt)
- 2 GAO Report Number 093513, Space Transportation System, February 1, 1975
link: (<http://archive.gao.gov/f0202/093513.pdf>)
- 3 CBO Report Number, Alternatives for Future U.S. Space Launch Capabilities, October 2006, pg 37
link: (<http://www.cbo.gov/doc.cfm?index=7635&zzz=34199>)
- 4 NASA FY09 Budget Request , page 463
link: (http://www.nasa.gov/pdf/210019main_NASA_FY09_Budget_Estimates.pdf)